MATERIAL AND SOCIAL CONSTRUCTION: A FRAMEWORK FOR THE ADAPTATION OF BUILDINGS

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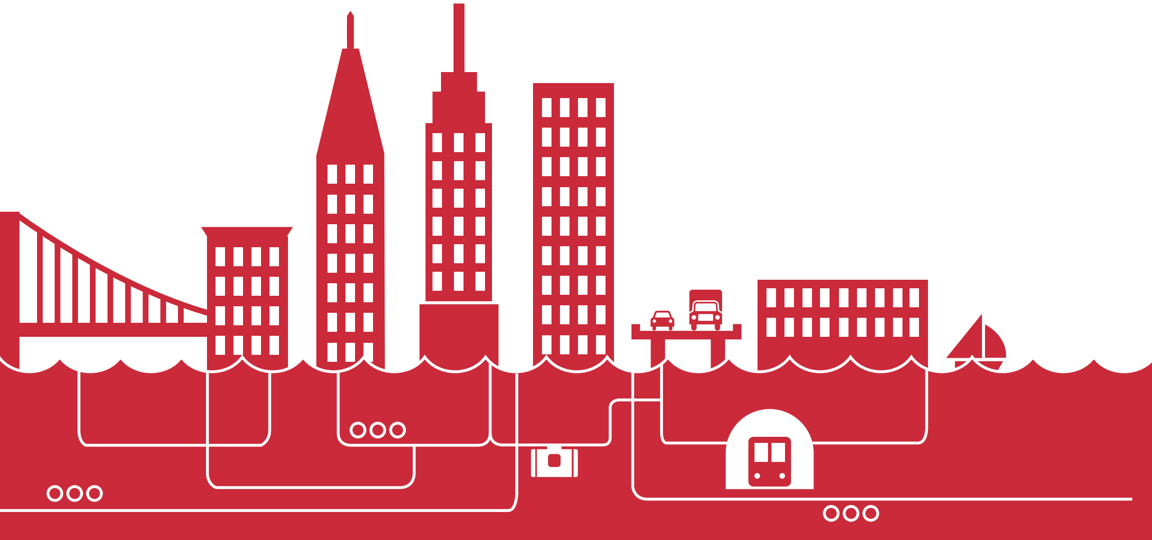

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ABSTRACT

This article is a formulation of a framework for understanding the nature of change, particularly climate change, as it applies to the scale of a building. Through an exploration of various scientific and social scientific literature, the article positions the concept of adaptation as the appropriate mode for understanding and managing change. Through the classification of a duality of material and social construction in the ontological composition of a building, various lines of thought relating to adaptive capacity and adaptive cycling within systems theory are appropriated within an integrated framework of adaptation. Specifically, it is theorized that as buildings as objects are developing greater capacities for integrated operations and management through artificial intelligence, they will possess an ex ante capacity to autonomously adapt in dynamic relation to and with the ex post adaptation of owners and operators. It is argued that this top-down and bottom-up confluence of multi-scalar dynamic change along an adaptive cycle is consistent with the prevailing theory of Panarchy applied in social-ecological systems theory. The article concludes with perspectives on the limitations of systems theory in architecture, future directions for research and an alternative positioning of professional practices.

Key Words:

Adaptation, Buildings, Building Systems, Climate Change, Resilience

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I. INTRODUCTION

The advent of climate change has accelerated the development of scientific and social scientific research into understanding the dynamic nature of change by and between complex systems and institutions. In a parallel state of paralytic development, architectural design research on the implications of climate change has largely been subservient in its relevance and application to the economic behaviors of the responsive modes of real estate production (Hertin et al. 2003; Stern 2007). In a limited capacity to-date, architectural design has been a proxy engagement for the incorporation of mono-technical solutions which serve to mitigate the occurrence of climate change justified through operational economic efficiencies (Etzion, et al. 1997; Giovoni 1998; Steemers 2003: Van der Linden et al. 2006; Schuetz 2011; Brown and Dixon 2014). Yet, in the face of climate change, the construction of architecture's aesthetic and semiotic power has the ability to preserve and advance forms of culture which escape economic unitization. As such, the conventional mitigation framework—often co-referenced as sustainability—is increasingly reaching a threshold of comprehensiveness, influence and development as the occurrence of climate change is now unstoppable by human action (IPCC 2014).

This article proposes a normative framework from which future theoretical and empirical research can advance the practice of designing and managing adaptive buildings. This framework is intentionally limited to the scale of the building and its users and not to the urban form, which has a different range of calculi and associated sets of methods and ontologies (Vachon, et al. 2013). This limitation at scale does not exclude from analysis the natural and urban ecological forces which shape the use and performance of a building. Instead, it merely acknowledges that the systems behind such forces have separate and unique capacities and cycles to accommodate change, even if such capacities and cycles are reciprocally dependent in some measure to the design and operations of a building.

Inherent in this exercise is an acknowledgement that the problem-solution set cannot be entirely optimized or engineered given the socio-ecological complexity of the challenges which are yet to be known (Bulkeley and Betsill 2013; Mazmanian 2013; Ovink 2014). As such, adaptation at the scale referenced herein is a set of dynamic multiscalar systematic processes which are referenced to a variety of stimuli that are not exclusively physical, ecological or climactic in their proximate degrees of influence. By extension, this adaptation framework is developed not as an exercise for explaining change but as a means to understanding and exploring the balancing of design intentions and management strategies which may be both anticipatory and reactive. From accommodating an aging society in Tokyo multi-family buildings to flood proofing commercial office buildings in New York City, a comprehensive framework for adaptive building design and management which bridges various scales, typologies and stimuli has yet to be explored.

The first step in the development of this nascent framework is the positioning of the concept of adaptation by and between a diverse sets of competing and interrelated concepts which have specific distinctions relating to actor orientation, time horizon, and system and institutional dynamics. Through the classification of a duality of material and social construction in the ontological composition of a building, various lines of thought relating to adaptive capacity and adaptive cycling within systems theory are appropriated within an integrated framework of adaptation. Specifically, it is theorized that as buildings as objects are developing greater capacities for integrated operations through the artificial intelligence of building systems, they will possess a capacity to autonomously adapt in dynamic relation to and with the adaptive capacity of managers and users. While building managers and users tend to adapt to stimuli after the occurrence of the stimuli (i.e., ex post), the artificial intelligence of adaptive building systems allows for the buildings as objects to possess a capacity based on both internal and external designs which can accommodate change at the time of or prior to the occurrence of various stimuli (i.e., ex ante). It is argued that this confluence of multi-scalar dynamic change which has the capacity to result in the realized adaptation of a building is consistent with the prevailing theory of Panarchy applied in social-ecological systems theory. The article concludes with perspectives on the limitations of systems theory in architecture, future directions for research and an alternative positioning of professional practices.

II. METHODOLOGY

This exploratory and qualitative research is primarily based on a comprehensive literature review of both the science of adaptation and the science for adaptation within a variety of science and social science domains (Swart, et al. 2014). To fill in the gaps between these external domains of theory and practice and that of architecture, select interviews were initially undertaken with practicing architects, landscape architects, urban designers and associated academics who teach adaptation and resilience based studios. The fifteen (n=15) interviews were semi-structured with a duration of approximately one hour and were conducted with faculty primarily teaching in the New York metropolitan area. Inquiries were made about the interviewee's experience in sustainable, resilient and adaptive designs and whether there was any operable knowledge in defining and distinguishing between these concepts, as well as whether any distinctions were ripe, necessary or relevant. The outcome of the research was consistent with the initial assumptions which motivated the production of this research. First, there was no consistency in the application of any of the concepts of mitigation, coping, resiliency and adaptation. However, all fifteen interviewees were able to correctly define mitigation as applied to either climate mitigation or hazard mitigation, but only five interviewees found common meaning between the two applications. When inquiry was drawn as to how these concepts applied in decisions within their professional practices, seven interviewees acknowledged that the primary impetus after Hurricane Sandy was rebuilding the status quo and that resiliency was largely a rhetorical device which cannot be meaningfully separated from risk mitigation. Thereafter, there was no definitional consistency, even for those who additionally practiced in environmentally sensitive geographies following the occurrence of Hurricane Sandy.

As such, the collection and interpretations of the data after Hurricane Sandy may be subject to certain convenience and availability biases (Nicholls 1999; Sunstein 2006). This is to say that the risks of flooding may impose a narrow frame of reference in terms of timing and response which biases a larger world view on climate change or any other social, environmental or economic stimuli. The categorical results of the interviews are not presented in this article; but, the disparate nature of the results: (i) reinforced the timeliness of the necessity to draw order by and between the concepts presented herein; and, (ii) contextualized the necessity to give a hierarchy of motivations (i.e., real preference for mitigation) by and between the concepts of response. As a consequence of this multi-method research design, it should be qualified that the truth of the existence of any framework as a higher ordering acknowledgment of actual phenomena by agents of artificial or natural intelligence can only be evaluated through the eyes of history and therefore escapes empirical confirmation and falsification short of critical theoretical validation. However, with the proliferation of the adaptive technologies described herein, there exists an opportunity in the future to empirically evaluate the framework of this article as applied in professional practice.

III. UNDERSTANDING CONCEPTS OF CHANGE

There exists today a great deal of variation in the meanings and heuristics assigned to a variety of concepts which address the nature of a response to change (Moser and Ekstron 2010; Preston et al. 2013). The distinction and definitional or conceptual consistency between the terms adaptation, mitigation, resiliency and coping is a practical hurdle to framework development in a variety of applied domains. This article attempts to assign order to these various concepts with the intent of positioning adaptation as the most appropriate concept with reference to the design and management of buildings. More specifically, it is acknowledged that the adaptation of buildings represents a duality of material (i.e., object) and social construction (i.e., managers/users) which creates a transient ontology from which science and social science applications of the foregoing concepts may be referenced.

Specific to climate science, adaptation is defined as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits mutual opportunities" (International Panel on Climate Change (IPCC) 2007a, p. 869). A more comprehensive definition of adaptation "involve[s] both building adaptive capacity thereby increasing the ability of individuals, groups, or organizations to adapt to changes, and implementing adaptation decisions, i.e., transforming that capacity into action."[Emphasis Added] (Adger, et al. 2005, p. 78). As discussed in the following section, the notion of capacity within the adaptation framework is critical to contextualizing the duality of building as an object and as a social construction.

As Uittenbroek, Janssen-Jansen, and Runhaar highlight, adaptation specific to climate change can be further categorized as a matter of governance versus process (i.e., specific measures) (2013). This is to say that adaptation may be an outcome of an active and willful intention, as well as a passive set of processes disconnected from deliberate manipulation. While resilience can be thought of as a preservation of the entire operations of the status quo of a host (i.e., a host may be an individual, a building, a community, an organization, etc…), adaptation is a gradual process of maintaining periodic points of resilience which ultimately results in a future state of being which is superior to its predicated state in its ability to flexibly respond and continue to be resilient to known and unknown external stimuli though, if necessary, a transformation of domains of operations. As such, resilient hosts revert to the status quo with a minimal change in their internal operations based on existing internal designs, while adaptation results in a superior post-stimuli state based on both internal and external designs. In this sense, adaptation can be defined as having the potential for transformability of the host to entirely different state of operations (i.e., program, use, intensity of use, services, etc…). The implications for this are not without costs, as transformation may not always be a smooth transition. Likewise, a host may become resilient to a specific stimuli, but it does adapt if it cannot become resilient to a slightly, dramatically or totally different sets of stimuli. Therefore, resilience and adaptation are closely related in that resilience is an internal process of adaptation along with mitigation and coping but each concept differs in their future states of being and their long-term implications in response to a diversity of stimuli (Nelson et al. 2007; Nelson 2011). In comparison, the following concepts each have their own criteria for occurrence, frequency, novelty and timing of stimuli (e.g., risks) and their associated modes of response.

Mitigation holds perhaps the clearest conceptual distinction in that it speaks to the prevention of the occurrence of the external stimuli of change. Mitigation is often used interchangeably to mean hazard mitigation or climate mitigation (i.e., preventing hazards or climate change from happening at all or otherwise reducing the vulnerability to the risk). However, climate mitigation is increasingly loosing relevancy as an exclusive matter of focus in that there is little doubt as to the probabilistic long-term occurrence of climate change. It should also be acknowledged that many acts of adaptation are also acts of mitigation and they may not easily be separated. For instance, adding a flood barrier in a building may prevent the risk of flash flooding but may also promote adaptation to sea level rise if storm surge is more frequently putting the building at risk. However, mitigation and adaptation may also work against each other with the classic example being that increased urban densities promote climate mitigation but make adaptation more difficult (McCovey, Lindley and Handley 2006).

In contrast, coping is a short-term responsive mechanism for the preservation of the minimum functions of host. Coping is very often utilized in a post-disaster context with the notion of rebuilding and recovery. This should be contrasted with resilience which seeks to maintain all of the operations of the host in the face of present stimuli based on internal designs. Coping has no internal design to respond to the same stimuli in order to maintain its full operations and therefore is relegated to the process of maintaining minimal functions. Coping is a concept originally borrowed from the field of psychology which evaluated individuals' ability to manage non-routine occurrences that are otherwise novel to the experience of the individual (Lazarus and Folkman 1984, p. 131). While the provision of emergency shelter and post-disaster psychological and financial counseling are laudable actions to once in a lifetime disasters, coping can very often be grounded in an emotional response with its own rationality that often conflicts with the long-term logics of adaptation. For instance, rebuilding a home which has been repeatedly flooded may serve to advance the coping of the residents but it does not serve to promote either resilience or adaptation. While a on-site flood barrier for these same homes may promote mitigation and resilience, it is unlikely to be an action of adaptation.

Again, in this scenario, an act of mitigation may or may not be an act of adaptation. Klein et al., make three major distinctions between mitigation and adaptation. First, as a function of time and scale, adaptation has long-term impacts distributed across a larger scale (i.e., global warming), with mitigation generally having impact over a shorter time horizon on a more localized scale (Klein, Schipper and Dessai 2005, p. 4). Second, citing the IPCC (2001a), they note that because of the two different scales and time horizons the costs and benefits to be "determined, compared and aggregated" differ (Id.). Finally, the sectorial distinction between actors and interests is highlighted as a matter of administration and policy creation. The authors acknowledge the IPPC's ambition to optimally mix mitigation and adaptation strategies, but they note that variable interests (Lempert and Schlesinger 2000), actors (IPCC 1996) and methods (i.e., cost-benefit analysis, cost-effective analysis, tolerable windows approach, game theory and multi-criteria analysis) (IPCC 2001b) makes optimization an almost impossible task with very little academic or professional consensus.

In comparison to coping, which is oriented towards a single and unique stimuli, resiliency as a responsive concept represents a systemized reaction to singular or ongoing stimuli whether known, unknown or otherwise anticipated based on internal designs. In predicate biological terms, the scholarship of resiliency can be traced to the field of ecology which attempted to move beyond static understanding of the equilibrium of ecological systems in favor of transient systems which explain evolutionary processes that result in either change or extinction (Holling 1973). As applied in an economic context, resilience has been defined as, "the ability to dynamically reinvent business models and strategies as circumstances change. Strategic resilience is not about responding to onetime crises or rebounding from a setback. It's about continually anticipating and adjusting to [change]" (Hamel and Valikangas 2003, p. 52). In its broadest sense, resilience can be defined as, "a multidimensional, sociotechnical phenomenon that addresses how people, as individuals or groups, management uncertainty" (Lee, Vargo and Seville 2013, p. 29). However, it could be argued that the uncertainty could be further refined to mean a state of unawareness of either the timing or depth of some occurrence that is within the realm of possibility or probability. For example, resilience to a catastrophic meteorite strike is a matter of luck and not managed process. Of course, the randomness assigned to "luck" could virtually apply to all outcomes; but, the process of managed resilience can at least have a measurable reduction in risk to reduce the negative implications of random events either happening at all or otherwise negatively impacting a specific host. To this end, many scholars have questioned the extent to which resilience can be distinguished from adaptation in their parallel efforts to maintain operational functions by virtue of a managed or developed flexibility (Id., p. 30).

The most useful performance traits of measuring resilience and adaptation—as borrowed from systems and computational theory—are robustness and reliability (Laprie 2008). Citing Anderson, Laprie defines robustness as a systems "ability to deliver service in conditions which are beyond its normal domain of operation" (Anderson 1988). From the perspective of computational theory, there are at least some conceptual distinctions between adaptation and resilience. First, resilience is often framed in a host's degree of robustness in its response as a matter of internal design, whereas adaptation may result in occurrence failure (or, some degree of failure) but my change for the next subsequent occurrence through the import of external designs (Woods and Wreathall 2008; Vogus and Sutcliffe 2008). This is often described as the transformability function of adaptation. Second, resilience is additionally defined by its time horizon and depth of impact. As noted by Wiggins,

> Resilience and adaptation are not identical. No system can be 100 percent resilient to all changes; there will be a threshold where it breaks down. Beyond

> that threshold, adaptation is the only option. For example, climate change is projected to cause sea-level risk that will submerge some communities. Those communities would have no option but radical transformation—the scale of change would beyond the resilience threshold where they could maintain their fundamental structures and functions. Also, adaptation has to be concerned with changes over 20, 50 or 100 years, not just the short term (2009, p. 79).

For as much literature as is cited herein, there is an equal or greater number of scholarly works which conflate the language of coping, resiliency and adaptation. This raises the pragmatic question as to whether the tautological distinction is indeterminate of the modes of analysis and/or evaluation of system or host responsiveness. This research focuses on adaptation as it represents the appropriate localized scale of buildings which are anticipated to face continued novel and anticipated stimuli occurring as a consequence of climate change. While these concepts are interrelated within a meta-application of adaptation, a conscience categorical distinctions between adaptation, resilience, mitigation and coping is useful when evaluating specific responsive actions at various scales by various hosts within the built environment. For instance, interviews have suggested that community planning groups and politicians are primarily concerned with coping (i.e., rebuilding) and resilience, while many engineers orient their practices to adaptation over the long useful life of infrastructure and other improvements. As a rhetorical proposition, this makes sense in that communities and politicians are incentivized to preserve the status quo of their representative constituencies. Likewise, the costs of transformation under adaptation are in contradiction to the tendencies of public policy to promote stability. However, it can be argued that all constructions of urbanity are in a constant and dynamic state of change. To this end, the rhetorical use of resilience to promote the interests and operations of the status quo may perpetuate structural inequalities which reinforce existing power regimes which are often less than truly progressive in their inefficient allocation of resources that are likely serving maladaptive ends over the long-term.

By contrast, the progressive implication of a superior state of flexibility imparted by adaptation is the highest order of outcome among the concepts. While conflicts may arise by and between the concepts, in a perfect scenario the manifestation of a capacity to cope, to mitigate and to be resilient can work in parallel sequence to the advancement of adaptation. Again, adaptation is about periodic points of resiliency which are maintained by a capacity to transform across domains in order to perpetuate resiliency. However, adaptation is not an ideology defined by the rhetoric of resilience but a process which is open to willful engagement. Preserving the status quo in a building through resilience or mitigation alone may not be desirable over the long-term, as the modification of behavior based on external influences (i.e., external designs) whether environmental, social or economic may require radical transformation of the recapitalization and use of a building. If buildings are exclusively designed to be resilient by an existing internal logic then the chance of failure (i.e., reduction in resilience threshold) is increased as the pace and diversity of change is accelerated with climate change. Therefore, while the transformation associated with adaptation from one regime to another will impart costs, those costs are assumed to be less than the cost of complete failure beyond the resiliency threshold. Although, if one were to think about the broader adaptation of cities, then the failure of a building which has reached its resiliency threshold may be a desirable outcome in that capital may be more efficiently allocated.

IV. DEVELOPING A FRAMEWORK FOR BUILDINGS: OBJECTS AND PEOPLE

The scalability of adaptation measures has been a critical barrier to the generalizable outcomes of the applied systematic study of adaptation (Cash and Moser 2000; Adger, Arnell and Tompkins 2005; Ostrom 2010). Within the built environment, crossing scales very often amplifies complexities and highlights the tensions between a diversity of actors and interests. For example, if an individual owner elects to build an integrated flood protection system (IFPS) at the scale of his building to protect the building from flooding, this is an act of mitigation and resilience as it prevents the building from flooding and maintains the operations of the status quo. Overtime, this may or may not lead to adaption. For instance, if a number of individual owners build IFPS for their individual buildings then it might lead to situation of maladaptation wherein flood waters are redirected to properties which might not have otherwise been flooded. So, what is resilience at one scale might be maladaptation at another.

To date, the study of adaptation has almost exclusively been oriented at the scales of organisms and ecosystems

(Schluter 2009; Mawdsley 2009; Losos 2010); local cultures (O'Riordan and Jordan 1999; Adger et al. 2009); business organizations (Nitkin, Foster and Medalye 2009; Linnenluecke, Griffitths and Winn 2013); institutions (Naess 2005; Agrawal 2010); local governments (Wilson 2006; Measham et al. 2011); and, national and international governments and organizations (Luterbacher and Spriz 2001; Aldy and Stavins 2003; Giddens 2009; Rübbelke 2011). The scale of buildings has been unexplored as an object of adaptive action and planning. One explanation for this oversight is perhaps an assumption that an examination of local public policies (e.g., building code, land use and environmental regulations) serves as an appropriate scale of inquiry because the policies result in the actualization of buildings which represent the value sets latent in the policies. However, as a practical matter, this is generally not the case even in the most sophisticated jurisdictions as there are economic and social variables associated with building design which escape the comprehensiveness of local public policy that is generally concerned with life and safety considerations which are set as minimum standards (i.e., flooding, systems continuity, ingress/egress, etc…)(Barton 2014).

Beyond the decisions and influences which impact the nature of the intent to design and manage a building, the building itself represents a hybrid composition for objectification because of the duality of its material form and the social construction of its design, use, management and interpreted meaning or symbolism. In its material manifestation, buildings represents a very clear delineation of a formal system with parameterized inputs and outputs, with building systems comprising an independent field of study. At the same time, its social utility defined by program is boundless not as a system with defined parameters but as a social construct, or even an institution, which is ever evolving and constrained only by its own historic path dependencies (North 1990; Thelen 1999). While some institutions within the built environment may be composed of systems of organizations, others may not. The endless variability in the nature of shelter suggests that the institutions of tenancy and tenure—and the management thereof—may be institutions which are not necessarily comprised of clearly defined systems.

As previously noted, adaptation is not just a meta-trajectory of resilience and mitigation measures which preserve the operations of the status quo that overtime transforms (or, has the capacity to transform) to a superior progressive state which maintains the ability to be resilient to known stimuli. It is also about a capacity within that superior state to be flexible in addressing (un)known or (un)anticipated stimuli. Therefore, the question is whether one applies theories of adaptation which are grounded: (i) in science oriented towards buildings as technological systems; or, (ii) in social science oriented towards designers, owners, operators and users? Alternatively, is there a certain hybridity which creates a hierarchy or panarchy of processes for evaluating resilience and adaption? Are these inquires ontologically grounded in the fiction of the building as an objective anthropogenic bystander (or, objective owner) or are they grounded in the realities of subjective multi-generational users? The answers to this fundamental problematique is seemingly clear cut. Buildings themselves do not innately adapt without the intent and action of man. Therefore, adaptation of buildings is a behavior which should be evaluated in the domain of social sciences.

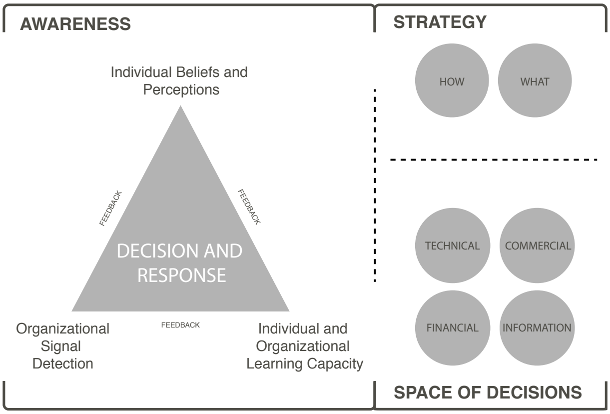
However, this perspective may not be so clear cut in light of the technological innovations in software and hardware design which have empowered an artificial intelligence in building systems to measure, register and adapt to environmental and user generated stimuli (Hayes-Roth 1995; Byun and Park 2011; Bia and Huang 2012; Kumar, Fensel, and Fröhlich 2013). As previously noted, adaptation is both a process and a deliberate willful imposition on a process set in motion by a combination of internal and external designs. Therefore, a building as an object may be taught to adapt—or, conversely, it may learn to adapt (Brand 1995). As internal operations of a software design are updated and reconfigured based on external designs, the likelihood of adaptation increases with the increase in pre-designed simulations which accommodate an increasingly diverse range of stimuli. There may eventually even be a future wherein some vast majority of stimuli (e.g., floods, heat waves, biological terrorism, etc…) are simulated within a reconfiguration of the software based on technologically expanding operational domains (i.e., mechanical, financial, etc...). Therefore, while the degree of willfulness vis-à-vis the intent of the software engineer may vary in time and space, the building as an object may possess a certain requisite artificial intelligence necessary for ex ante adaptation, in addition to ex post adaptation. Ex ante and ex post being defined as a design for response internalized during/before or after the occurrence of a stimuli, respectively. In this case, ex post adaptation for buildings is the point of reconfiguration or updating of the software following occurrences which are outside of the domains of the building's software. Admittedly, at present, there are functions of buildings which elude measurement and system automation. However, it is possible to envision a future in which every facet of operations, maintenance and capitalization are tactically and strategically evaluated and executed by an integrated computational platform subject to human judgment. With automated valuation models and the MERS system, an integrated artificially intelligent building may even have the capacity to mortgage itself one day. [1]

The other end of spectrum is the social construction of buildings which are composed of people, organizations and institutions which manage and use the material form. Adaptation can further be refined to be the object of not just climate change in its physical manifestation but also the variability and uncertainty inherit in the concept itself (Smith, et al. 2000, p. 227; Hallegatte, 2009). Uncertainty being an innately human characteristic. The origin of the process of adaptation can either be "autonomous" (i.e., automatic, spontaneous, passive or natural) or "planned" (i.e., deliberate, strategic or active)(Smith, et al. 2000, p. 239). In the only published paper on the adaptive capacity of real estate developers, Hertin, et al., cite three variations of the theoretical application of adaptation measures by individuals and/or organizations (2003). First, there is the 'Dumb Farmer' hypothesis which says that there is no adaptation undertaken at all. Second, there is the hypothetical "ex post" (or, efficient) adaptation strategy which "occurs only after the costs of not adapting have become apparent" (Id., p. 279). Finally, there is the "Clairvoyant Famer" hypothesis, or "ex ante" adaptation, which dictates that the host will undertake near perfect measures to expected future change. The authors argue that these divisions do not necessarily reflect how businesses—notably building developers and owners—actually operate.

It could be argued that businesses that fall into the Dumb Farmer category would eventually go out of business, as they have to position themselves within markets which are in a constant state of adaptation. This assumes that markets at least partially internalize and transfer the cost of climate change. Likewise, it seems unlikely that any business—or, building owner/manager—would have the requisite intelligence and resources to anticipate the existence or occurrence of a wide range of potential stimuli and undertake ex ante adaptation in perfect concert. However, an artificially intelligent building system with a capacity to iteratively respond to thousands of stimuli might have the capacity to undertake ex

[1] This is perhaps the most extreme example of "robo-signing."

Diagram 1: Framework for Adaptive Capacity of Firms (User / Manager)

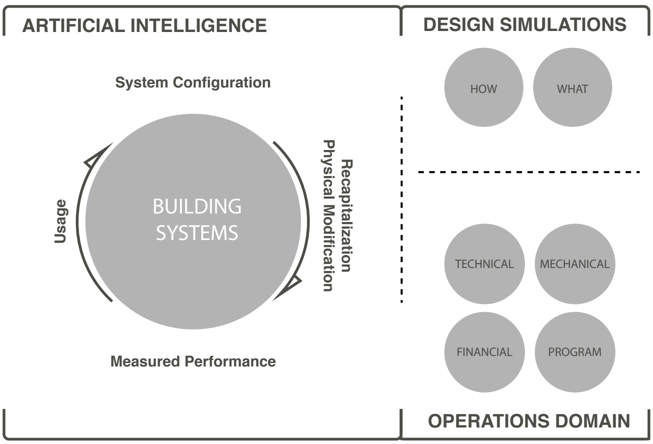


Source: Adapted from Berkhourt (2003); Hertin, et al. (2003); Arnell, et al. (2006); Frankheasuser, et al. (1999)

ante adaptation—or, something very close to it. This ex ante adaptation would theoretically be considered autonomous by virtue of its automatic response and not subject to human strategy and deliberation imbedded in the exercise of a plan in the conventional sense. However, this distinction is not entirely so clear cut in that strategic human intervention would arguably be designed within the software. In this sense, the distinction is about execution and not intent.

However, reality is much more complex. Even as a building system autonomously adapts ex ante, some measures would require human judgment which may be less than informed and whose outcome may be less than logical. Likewise, those actions may be subject to a historical plan of adaptation or resilience which is less analytically sophisticated than the building's software. This is at least one scenario, as the inverse could also be true. Fankhauser, Smith and Tol (1999) conceptualized the interrelationship between autonomous and planned adaptation by noting that the relationship between the two could be framed as a matter of economy. The measures could be 'complementary' in that "[planned] adaption increases the marginal benefit of [autonomous] and vice versa." (Id. at pg. 70). By example, a planned measure to change acquisitions strategy away from flood prone buildings may increase the marginal utility of autonomously

Diagram 2 : Framework for Adaptive Capacity of Buildings (Objects)



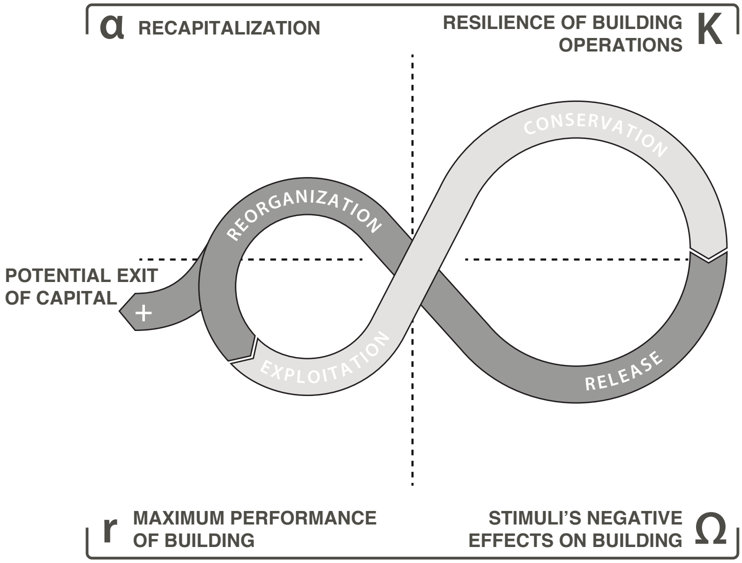
imposing flood gates on the limited number of existing buildings in one's portfolio. The expensive unit costs of flood gates may not have a reasonable return on investment (i.e., lower insurance premiums or deductibles) for the entire portfolio, but may have a greater utility in a limited number of select buildings. The other linkage between autonomous and planned adaptation measures is that of 'substitute' measures (Id.). In this scenario, planned measures may completely substitute autonomous measures. Substitutes are more capital intensive and are based a relative confidence of occurrence which makes their pure application somewhat suspect as a practical matter. As such, Fankhauser, et al. suggest that there is balance between these two which are in constant flux as information, vulnerability and general capacity change and evolve.

This balancing act is precisely the nature of the aforementioned duality of buildings. In practice, a building might have its own autonomous adaptive capacity to learn and take action through software reconfiguration, but it is also subject to the human judgment of an owner and/or operator which is generally undertaking, in the best case scenario, planned and ex post adaptation. As represented in Diagram 1, intelligence and beliefs within an organization are a critical component of adaptive capacity within a social construct—in this case firms which are a proxy for owners, users and managers. (Frankheasuser, et al. 1999, Hertin, et al. 2003; Berkhourt, Hertin and Arnell 2004; Arnell and Delaney 2006). The capacity to gather, filter, and interpret data both as an individual act and as an act within an organization are dynamically related to and reciprocally dependent on both strategy development and the space of decisions from which they can act with the intent to be resilience and/or adaptive. A recent study of commercial real estate firms in New York City found that corporate and building level strategies were entirely ex post and resulted in planned measures (Keenan 2014). There were no observed actions or strategies which could be defined as autonomous or ex ante. Likewise, it was determined that the adaptive capacity of subject firms was largely driven by human and organizational intelligence (Id.)

As a consequence of the duality of buildings, there is also a certain duality of adaptive capacity. Buildings as objects have the potential for an autonomous ex ante capacity, as per Diagram 2. Instead of beliefs and organizational intelligence gathering leading to strategies, the artificial intelligence of buildings operationalized by measuring and reconfiguring the operations of systems leading to and responsive of simulations based on a domain of operations, which itself is subject to re-registration. In both capacities, the underlying intent to is to recognize, process and respond to stimuli based on a complex set of values.

This relationship (i.e., ex post v. ex ante or top-down v. bottom-up) highlights a critical debate within adaption scholarship as to whether there is a hierarchy or panarchy of influence in stimulating adaptive cycles within systems (Gunderson and Holling 2002; Walker et al. 2006; Gotts 2007; Allen et al. 2014). Systems have been observed to go through fairly predictable cycles of growth, development and decay. In an adaptive cycle, elements of a system interact at various scales to propel a system across phases of exploitation (r), conservation (k), release (Ω), and reorganization (α) (Holling 1986). While it is not opined that all social, material and ecological phenomena are reducible to systems theory, there is an argument to be made that the design, production, and technical operation of buildings falls within clear parameters of one or several systems with discrete inputs and outputs. Likewise, it can analogized that buildings are subject to adaptive cycles often aligned with component life and financial cycles, as represented in Diagram 3. For instance, the perpetuation of the operations of the status quo, or resiliency, are occurring within the conservation (k) phase. The recapitalization of increasingly adaptive building happens

Diagram 3: Buidling Adaptation Cycle under Theory of Panarchy



in the reorganization (α) phase following the negative effects of stimuli during the release (Ω) phase. The high point in the efficiency and productivity of the building in terms of use and capital accumulation occurs during the exploitation (r) phase, at which point capital may exit the cycle (i.e., sale or mortgage refinancing).

The conventional theory of Hierarchy is that there are large slow moving variables of influence and small fast moving variables (Allen and Star 1982; Simon 1991; see Figure 1, Brand and Jax 2007). As such, a stable system regime is a state mediated between the fast and slow variables which resist and promote change, respectively. It has been theorized that the top-down slow variables create restraints on fast variables below it. As Gibson, Ostrom and Ahn notes, "[t]he levels immediately above and below the referent level provide environmental constraints and produce a constraint 'envelope' in which the process or phenomenon must remain" (2000, p. 225). This theory has been challenged on numerous grounds with the principle critique being that complex systems often operate in non-linear dimensions of time and space and that cause and effect across scales is empirically troublesome to isolate in an intermediate state of analysis (Id.)

In contrast, the prevailing theory of Panarchy argues "that control is not just exerted by larger-scale, top-down processes, but can also come from small scale or bottom-up processes…. Because of the potential for cycling within adaptive cycles to affect both smaller scales and larger scales, panarchy theory emphasizes cross-scale linkages whereby processes at one scale affect those at other scales to influence the overall dynamics of the system." (Allen et al. 2014, p. 578).[2] This is precisely the nature of the continuous linkage along points of the adaptation cycle as represented in Diagram 3. While top-down design and management of buildings is subject to social, organizational and institutional processes, the realized adaptation cycle of buildings is also subject to ground-up autonomous processes from the building as artificially intelligent object. These processes link across scales and reciprocally influence their respective capacities, as represented in Diagram 4.

It is helpful to conceive of two types of stimuli in the framework. The first set of stimuli are unrecognized stimuli which may be social, environmental and/or economic in their origins. The second set of stimuli are those stimuli which have been intelligently processed based on the respective dual capacities. For example, information from a building system may inform where along the adaptation cycle the building is so as to inform a corporate portfolio strategy which may in turn dictate the capitalization of a related building system that results in greater realized adaptation along the reorganization (α) phase. Without the artificially intelligent system to translate unrecognized stimuli to recognized stimuli, the same or similar outcome as to the foregoing example is less likely in terms of realized adaptation. More precisely, artificial intelligence leads to mitigation and resilience—even hemostasis—in the short-term. What makes it adaptive is its capacity to simulate and recognize stimuli which are unanticipated by human and/or organizational capacities and which themselves can be reconfigured as circumstances evolve. To this end, the framework links capacities with realized adaptation as positioned with the adaptive cycle of a building which is driven by a variety of intelligent and unrecognized stimuli.

Together these processes which are made up of multiple sub-processes which are dynamically interlinked across scales. Therefore, it would be a gross simplification, for example, to argue that financial investment criteria will exclusively dictate adaptation of a

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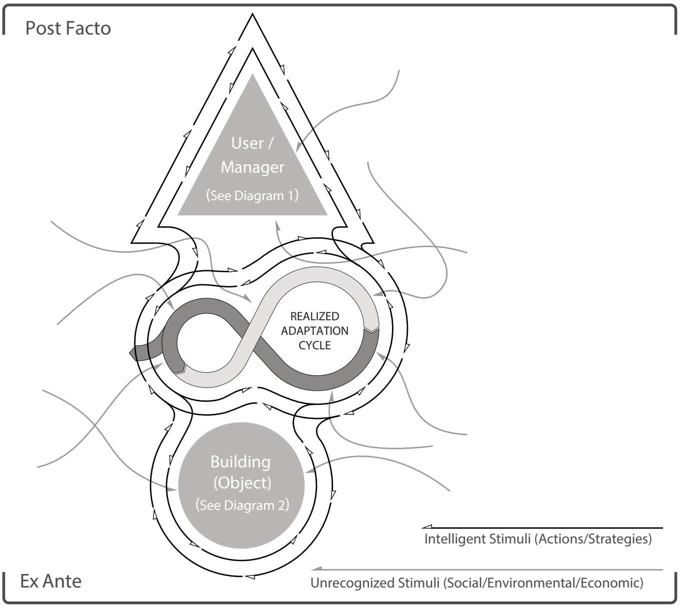
[2] For application of Panarchy Theory to urban systems, see Bessey (2002); Garmestani et al. (2005); Garmestani et al. (2008).

Diagram 4 : Framework for Multiscalar Dynamic Adaptation of Buildings



buildings in the future, as is the present dominant rationality of mitigation and sustainability. Financial criteria may have a principle influence on the capacity and actions of the top-down processes of an owner/operator organization but are not necessarily determinate of the bottom-up capacities which may or may not be determinate of the long-term realized adaptation of a building. In this sense, realized adaptation is the actual adaptation which is subject to bottom-up and top-down processes. This doesn't mean that there is equal weighting of influence from these differing modes of adaptation (i.e., capital may still dominate realized adaptation, for instance), but it acknowledges a more dynamic system of influences which itself has the capacity to adapt as technology and innovation respond to change. Therefore, the capacity of a building is composed of the two sub-capacities identified in Diagrams 1 and 2 and whose sum is greater than its parts, assuming the non-occurrence of maladaptation.

Finally, it should be cautioned that this system of adaptive capacity can also promote maladaptation. While a robust capacity may increase the likelihood of adaption, there may be forces at work, willful or otherwise, which may reduce capacity to a point which results in a state of maladaptation. As one moves out of the built environment and beyond the scale of the building framed herein, it also worth acknowledging that adaptation of buildings may conflict with other societal responses to climate change. For instance, if the global real estate community in cities subject to high-risk of flooding were to fortify their buildings with more concrete and steel, then the energy, resources and pollution expended in this effort might conflict with climate mitigation goals and might draw resources away from other modes of societal adaptation. As such, this framework should be contextualized across urban, regional and global scales to give meaning not to its inherent utility but to the implications of the broader impacts of the adaptation of buildings.

From the designers point of view this complexity underscores the necessity to frame the design and operation of buildings within a complex array of processes with varying levels of human and artificial intelligence. A fundamental aspect of the concept of adaptation is an ability to be flexible while traversing through a state of transformation. Transformation may manifest itself in everything from changing programs (i.e., from hospitality to senior housing) to the intensity of existing uses. The conventional problem set of designing flexible interiority to a building to accommodate future alternative programs is just one of several exercises in conceiving of a comprehensive design (Sinclair, Mousazadeh, and Safarzadeh 2012). In this sense, interior adaptability is just a method within adaptation. Architecture has struggled with adaptation as demonstrated by several generations of failed experiments in modularity. However, there is a an opportunity to develop practices in adaptive design beyond the rules of thumb for open plans, durable materials, low maintenance and an accommodation for future expansion.

As such, thinking about how a building is used and operated and how those criteria can be measured to inform both artificial and human intelligence will be critical in the future. Likewise, having a sensitivity beyond the physicalities of the building to understand management processes and their influence on the intermediate resilient state of operations is also critical to contextualizing design within human and environmental conditions. Each of these scales and sensitivities require a facility in a variety of skills and disciplines, including architecture, process engineering, computer science, real estate development, urban planning, facilities planning, material science, operations planning and a multitude of other disciplines. This requisite diversity of knowledge reinforces the notion that professional practices within the built environment are both an art and a science—or, in this case, social science. Ultimately, one or several professions will need to be positioned to mediate language and values by and between the various disciplines in the advancement of adaptation. Will this be the roll of the architect?

V. EXPLANATORY SCENARIO WITHIN FRAMEWORK

It should be acknowledged that number of key architectural figures in recent history, such as Buckminster Fuller, Christopher Alexander and Frank Duffy, have endeavored to synthesize these varying domains of knowledge into an contemporary architectural discourse. However, it is the work of Stewart Brand, notably in How Building's Learn: What Happens After They're Built (1995), which weights heavily on the application of the framework developed herein. Brand's perspective on the adaptation of buildings was one grounded in the necessity to develop internal designs which can accommodate inevitable human adaptations. Brand went so far as to draw reference to a Theory of Hierarchy in his own work in that he conceptualized fast bottom-up and slow top-down influences—largely social and economic (Id. p. 17). Although, with a measure of clarity not quite ripe at the time, he tempered that conceptualization by citing Holling and the theoretical extent to which fast and slow variable may shift hierarchical functions across scales (i.e., consistent with Panarchy)(Id.). In many ways, the framework developed herein picks up where Brand left off in that it accounts for technologies—adaptive censors and buildings system and their associated modes of artificial intelligence—which simply did not exist at the time of Brand's research.

Therefore, the questions are: (i) what are some of the existing adaptive technologies; and, (ii) how could they be referenced to explain the framework of adaptation? By example, currently adaptive lighting, ventilation, façade and energy management systems are being developed and selectively utilized in the U.S. (Hoberman and Schwitter 2008; Erikson 2013; Hansen 2013). These systems are being utilized in new buildings, which for the sake of argument will be subject to changing climactic conditions in the future. One example of adaptation is a scenario wherein the energy management system measures the performance of the other systems and forces calibration on the time and mode of use so as to promote energy efficiency. This serves to both mitigate the risks of overconsumption, for instance on hot days, and it is adaptive because it forces utilization of the building systems beyond their initial configured domains of operation. Likewise, the energy management system outputs could also be adaptive to the extent that building managers utilize the outputs of the energy management system to inform tenant use (e.g., incentivize night time super-computing).

In this scenario, as excessively hot days occur more frequently, let's assume the mechanical façade systems are being utilized beyond their intended design for durational stress and the façade system malfunctions. The building owners and managers now have to decide whether the capital costs for fixing or upgrading the façade system justify the amortized return on investment relative to the modeled reduction in energy costs. In this scenario, the owners and managers decide that the replacement costs far exceed their benchmark for amortized returns. They also realize that by reallocating some fraction of the façade replacement cost to upgrading the software configuration for the other systems they will be able to realize a net efficiency gain. The scenario could be extend to assume that thirty years later the super-computing tenants no longer remain and the building transforms programs (i.e., domains) to accommodate tenants with much lower energy consumption. At a point in time when the life cycles of the original lighting and ventilation systems require a similar evaluation under a cost-benefit analysis, it is determined that both systems justify recapitalization because the reduction in energy use from newer more efficient tenants doesn't offset the greater demands from ambient, radiant and convective heat caused by global warming.

The realized adaptation at each stage could have only been accommodated with this measure of precision and corresponding efficiency with the benefit of outputs from the artificially intelligence building systems and the judgments of the owners and managers, which were informed on some measure by the artificial intelligence. The question then is could adaptation have happened without these intelligent building systems? Yes, the owners could have kicked out all of the super-computing tenants to reduce their energy burden. However, the high priced rents the super-computing tenants would have paid could have resulting in lower levels of overall capitalization resulting in a shorter life cycle of the building. In either event, the scenarios for adaptation and maladaptation are nearly endless in their manifestations one way or the other. The framework herein only reinforces the capacities of user and managers who will never be completely substituted in their judgments by artificially intelligent buildings. It is likely not possible nor is it desirable that this substitution takes places given that buildings ultimately serve the interests of human habitation. If buildings were truly artificially intelligent, then it is likely that humans would be excluded from occupancy in the advancement of adaptation. The advantage of this framework is that it sets the stage for developing more robust human capacities which promotes the effective, efficient and timely allocation of resources along the adaptation cycle of a building with the intent of maximizing the probability occurrence of adaptive versus maladaptive outcomes.

VI. CONCLUSIONS AND FUTURE RESEARCH

The academy of architecture has long struggled to manage complexity without succumbing to the external parametric applications of systems theory. While not explicit, one could argue that this reservation has been grounded in a variant theory of Hierarchy wherein influences outside of the hand of the architect are dictating aesthetic and programmatic gestures which dilute—or more formally limit—the creative capacities of architecture which sits within an hierarchy of capital and culture. It is not a pure coincidence that architecture complains of the limitation of the "envelope." Must applied systems theory in architecture be reduced to an architecturally void "technological sublime"? (Wolfe 2006, p. 5). At the same time and at a different scale, hierarchy has been deemed, with all of its classical sensibilities, to be the Third Law of Structural Order (Salingaros and Mehaffy 2006; Tracada 2013). However, this rhetorical tension is largely one of aesthetics and itself represents a certain panarchy of influence between the ordered, random and chaotic gestures of architectural expression.

But, analysis and expression are process and outcome. While this division is not so clear in light of the aestheticization of data visualization and the practice of improvisation, it highlights the role of the framework developed herein as analytical with very limited generative applications. This is perhaps both a strength and a weakness. But, this framework fits within an analytical theory of architecture which acknowledges the practice as both an art and a science (Hillier 1999). At best, its implications are for propelling the professional domain into realms of intelligence and knowledge which modify workflows and processes to accommodate changing conditions. The current set of professional ethics apply to the lawful state of construction of a building on day one, would or should that ethic be extended throughout the building's useful life? At worst, it is a framework which is not quiet ripe in light of the current reality of buildings which are not so intelligent. To this end, it serves as a challenge to give greater dynamic consideration to the autonomy of the building as an object—albeit a systemized object.

By giving resolution to the dual capacities of human and artificial intelligence of a building defined by its material and social construction, the framework for the dynamic mutliscalar adaptation of buildings draws a nexus between the adaptation cycle of a building and the varied social, economic and environmental forces which are shaping the built environment. Ultimately, artificial intelligence serves not only as an adjunct for human judgment but as a powerful barometer of unrecognized stimuli. The future development of this framework will be advanced by case studies which inquire as to the nature of the decisions which frame the selection, operation and recapitalization of adaptive building systems. Thereafter, the framework could be advanced by understanding the methodologies associated with these decisions along varying trajectories of the adaptation cycle as mediated by the dual modes of intelligence (Wilkinson, Remøy and Langston 2014). Implicit in this exercise is an elucidation of the values which speak to the weighting of priorities for the allocation of limited resources.

Future research in architectural technology could therefore explore how technology is actually interpreted and utilized by owners and operators. To this end, research could be extended to give consideration to positive behavioral modification through not only conventional building systems but latent and patent spatial constructions—which themselves may be systematized in the future. Deeper explorations of technology which serves not just efficiency seeking ends but are themselves reconfigurable to changing conditions wherein efficiency in one state might be inefficient in another. Research into various simulations which are responsive to a litany of stimuli which are configurable to a mode of action is a task with no end in light of a world subject to constant and accelerated change. Ultimately, this framework for adaptation acknowledges a duality of material and social construction in buildings which is ripe for the appropriation of developments in scientific and social scientific knowledge in the willful steering of adaptation cycles which are informed by natural and artificial modes of intelligence. In this context, design research is uniquely positioned to further develop synthetic lines of knowledge which are responsive to a world defined by conflicting realities grounded in art, science and social science. Architects and the society to which they serve cannot afford to be the 'dumb farmers' any longer.

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CURE. The Center for Urban Real Estate GSAPP Columbia University

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Jesse M. Keenan is the Research Director for the Center for Urban Real Estate (CURE.) and Adjunct Professor of Real Estate Development at the Graduate School of Architecture, Planning and Preservation at Columbia University. Keenan has previously advised on matters concerning real estate and housing for agencies of the U.S. Government, including Fannie Mae and the Federal Deposit Insurance Corporation, Fortune 500 Companies, not-for-profit community enterprises and international development NGOs. Keenan has previously held various teaching, research and visiting appointments at the University of Miami School of Law, Harvard University's Graduate School of Design and Joint Center for Housing Studies, the University of Amsterdam and The Bauhaus Academy in Dessau, Germany. Keenan previously served as is a member of the U.S. Department of Homeland Security's Regional Disaster Sheltering and Housing Recovery Planning Team and as a member of Mayor Bloomberg's NYC Task Force for Building Resiliency. Keenan currently leads CURE.'s joint project with various agencies of the Netherlands for advancing climate adaptive development research and serves on the Climate Change Working Group for the 4th Regional Plan for the tri-state New York metropolitan area under the auspices of the Regional Plan Association. In a professional capacity, Keenan advised the Rebuild By Design competition on matters relating to financing and insurance and is presently working on the design and development of NYC's Seaport City.

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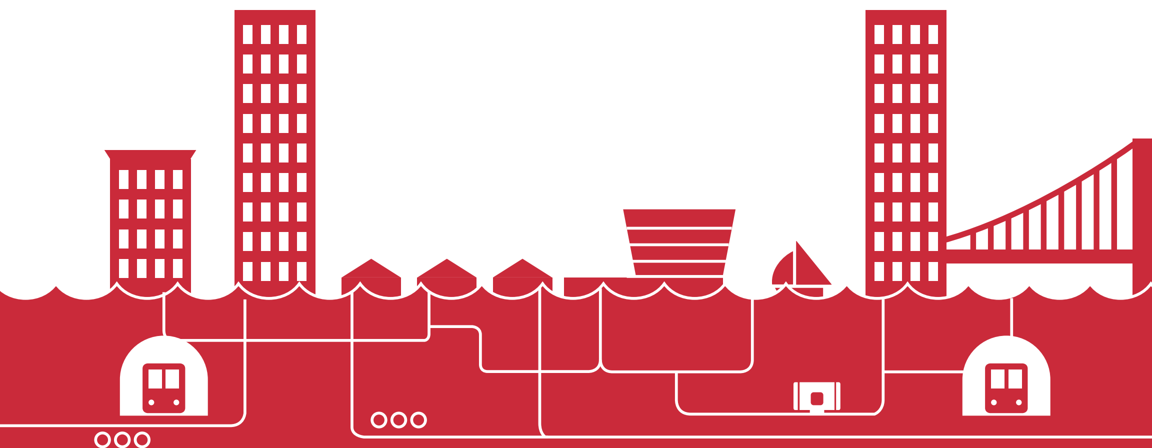

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